International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

Electrolysis Remediation of Heavy Metals By Using 2^d Hexagonal Electrode on The *Leachate* From Final Disposal (Landfill) Sitimulyo Piyungan Yogyakarta

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Abstract: ***Leachate is liquid that permeated through rubbish heap that contained of organic/inorganic substances and heavy metals which influence human health if it accumulated in human body. Some types and number of heavy metal ions contained in leachate determine rate of pollution in the leachate's original place. To eliminate content of heavy metal ions of leachate, this research used Electrolysis Remediation method using 2-D hexagonal electrode. It was expected that, after the electrolysis remediation process, content of heavy metal ions of leachate could be reduced, so that it existed under threshold. Leachate analysis used electrolysis remediation observing pH, resistivity and concentration of heavy metals, such as Hg, Cu, Cr, and Cd of leachate before, during and after processing the electrolysis. Results of research indicated that contents of leachate in Hg metal ions were 2.149 ppm; Cu, 0.074 ppm; Cr, 0.272 ppm; Pb, 0.161 ppm; and Zn = 0.340 ppm. For Cd was not detected in the leachate but existed in cathode deposit as much as 1.907 ppm However, concentration of the metal ions was different to each time because rubbish in TPA was also different. Process efficiencies for Hg were 93 %; Cu, 0%; Cr, -1266 %; Pb, -19 % and Zn, 48 %. Efficiency process of electrolysis remediation was highly influence by distance of cathode and duration of remediation process. Closer distance from cathode, time taken for remediation process was longer; also, farer distance from cathode, the efficient remediation process would take longer time.***

Keywords: Leachate, Heavy Metal, Electrolysis Remediation,2-D Hexagonal Electrode.

1. Introduction

Urban growth with the industrial development is not only lead the increasing of people prosperity, but also creates a new problem that associated with the environmental pollution by discharges of industrial waste, especially by the increasing of garbage from time to time.

Each cities havea a special area which used as the final disposal (landfill), as well as Yogyakarta the city. As a city with a population of inhabitants about 12.897 per km2, or it was about 419.152.5 people in 2005 **[1]**, so that the problem of waste was a matter that required a special attention. Therefore, the local government of Yogyakarta city is setted an area about 20 hectares in Ngablak Area, Sitimulyo Village, Piyungan District, Bantul Regency as the one of Landfill. This Piyungan landfill, every day could be received about 350-400 tons of waste from the three regions such as Sleman regency, Yogyakarta and Bantul Regency **[1], [2].**

The heap of garbage in the Piyungan landfill is needed to be handle seriously, because the number of incoming wastes were so much in every day would be decreasing an environment quality in the landfill, and also around of the landfill. Degradation of an environmental is caused by the piles of garbage that was producing a kinds of waste such as malodorous gaseous, the solids which is can not be decomposed in the soil, as well as a liquid waste (*leachate*) that was contaminate a groundwater and river, as well as the heap of waste can be a source of disease **[3].**

Leachate is the hazardous waste liquid, which is occurred as a result of the interaction between water infiltration with heap of solid waste in the landfill located **[4].***Leachate* characteristics in general, which has a value of BOD (*Biological Oxygen Demand*) and COD (*Chemical Oxygen demand*) were high, the degree of acid (pH) is low, high-containing organic compounds such as chloride and also contain a heavy metal ions that was polluting an environment **[5], [6].**

Leachate Sample that is obtained from Piyungan landfill was containing a number of contaminants in the form of ions that have a high concentration, namely Sodium (Na), Calcium (Ca), Magnesium (Mg), Potassium (K) and Chloride (Cl), which has a great potential to pollute and degrade the quality of ground water **[7]**. By seeing so many types of wastes that is throw away in the Piyungan landfill, so that it does not cover the possibility if the *leachate* that was generating is also contained the heavy metal ions as a source of harmful pollutant such as Hg, Cu, Pb, Cr, and so on. The magnetic mineral that is contained in the *leachate* from the Jelekong landfill, outside of Bandung city which was magnetite (Fe_3O_4) that is played a role of the soil contamination **[8] - [10]**.

The existence of heavy metals in the *leachate* substantially is very affected a quality and quantity of the *leachate*. To eliminate the existence of heavy metal in the leachate, the one measure that can be taken is to restore (remediation) a *leachate*. The leachate recovery by electrolysis was the one effort to recovery a leachate that have contaminated a heavy metal from the other organic contaminant by *in situ*. The remediation technology in its application by using a low cost and it is very potentially used for a various type of contaminant **[11], [12].**

In this study, it is used a method of electrolysis remediation by using 2-D hexagonal configuration. The ions binding of heavy metal by the cathode on the using tools in this method, is expected to decrease the concentration of heavy metals in the *leachate*. In addition, how many the contact time influence and the distance toward the decreasing of heavy metals level in the remediation process of electrolysis is to be noted. The effectiveness of binding by the cathode was certainly different for each types of ion. Therefore it was necessary the decreasing the concentration of heavy metal ion in the *leachate* as the result of remediation was also not same.

Thus, this study is aimed to identify the containing compounds in the leachate, that is obtained from the Piyungan landfill, especially the content of heavy metal and to determine the efficiency of decreasing the concentration of heavy metal in the *leachate*, that was contaminating by heavy metal by using the remediation electrolysis with configuration of 2D hexagonal, as well as to determine how much the influence of the time and distance to the level decreasing of each heavy metal in the remediation process of electrolysis by using 2-D *hexagonal* configuration.

2. Methods

2.1. Material and Method

This research is conducted in the Laboratory of Geophysics, Faculty of Mathematic and Natural Science (MIPA), GadjahMadaUniversity.

Which is to be an object or material in this study were in the form of *leachate*, another material that is water as a rinse. While a tools that are used include: Jerrycan is used as the container to take the *leachate* sample. Leachate's container from the glass is used as a process of electrolysis, *Power supply*, Pipette, Electrodes, Ohm meters, pH meters, Mixer, Cable, Multitester, 20 ml size's glass bottle as a sample place and AAS for concentration analysis of each heavy metal in the leachate sample.

Leachate sample is taken from Piyungan landfill about 300 liters and it is incorporated into 10 units of 30 liter size's Jerrycan. After arriving in the laboratory, it is incorporated into the glass container by sizes about L × W × T = 1 m × 1 m × 60 cm. It is used a stainless steel electrodes in the shape of cylindrical. The entire surfaces of the electrode are inserted into the leachate samples vertically with the distance between the electrode 45 cm by using a 2-D *hexagonal* configuration (Figure 1).

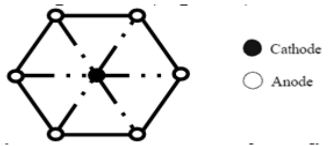

Figure 1: 2-D *Hexagonal* Configuration

The process is carried out during 2.5 hours. It is conducted an observations on each samples and the taking of leachate sampling on each sampling point, by a time span in every 30 minutes (for this observation, the electric is turned off). In this study, the sample taking is conducted in the three areas in the glass reactor namely Area I (located about 15 cm from the cathode), Area II (located about 30 cm from the cathode) and Area III (located outside of the electrode area) the sample is analyzed by using AAS to see the concentration from the target of each heavy metal ion.

2.2 Data Analysis

To determine each ion decreasing efficiency concentration of heavy metal after implementation of leachate remediation by electrolysis is by used the following equation **[13]**

$$E = \frac{C_{awal} - C_{akhir}}{C_{awal}} \times 100\%$$

Specification: E = Efficiency (%)
C = Concentration

3. Result and Discussion

The media is used in this study was a leachate that is obtained from Piyungan landfill Yogyakarta. Before the leachate sample is taken in the large quantities (300 liters) for the remediation process, firstly it is conducted an initial sampling taking, by aim to see whether the targer of heavy metal concentrations was in the leachate (detectable) or not. The selection of the target heavy metal is based on that metal's ability to pollute the environment (based on its ability to cause the toxicity) and it is also based on the type of waste that is existed in the area of Piyungan landfill from the preliminary observation. The analysis result of initial sample can be seen in Table 1.

Table 1: Heavy Metal Type and Its ConcentrationIn The Leachate from the Piyungan Landfill Yogyakarta.

No	Type Metal Weight	Concentration	Maximum allowable levels *)
1.	Mercury (Hg)	2,149 ppb	-
2.	Lead (Pb	0,161 ppm	0,1 ppm
3.	Zinc (Zn)	0,340 ppm	5 ppm
4.	Chromium (Cr)	0,272 ppm	0,1 ppm
5.	Cadmium (Cd)	No detection	0,01 ppm
6.	Copper (Cu)	0,074 ppm	1,0 ppm

Note: *) Manahan Source (1994) **[3]**

Ions of heavy metal such as Hg, Pb, Zn, Cr, Cd and Cu that are also contained in the leachate of Piyungan landfill, because the water waste of urban and the garbage dump of household, as well as industry were artificial sources for the content of Cd, Cr, Cu, Fe, Pb and Hg **[14]**.

On the analysis result of initial sample with AAS method, it is seen that there were certain metal ions, such as zinc, copper and cadmium, that its concentration in the leachate has not crossed yet the limits of maximum level that is the allowed, but it is needed to remember that the accumulation of these ions would be very dangerous, so that in this study it was also carried out the observation against the concentration of these ions.

3.1. Remediation Process Result on the Concentration of Heavy Metal Ion In Leachate

3.1.1. The Content of Mercury (Hg).

The research result about mercury (Hg) on the leachate can be seen in the Figure 2.

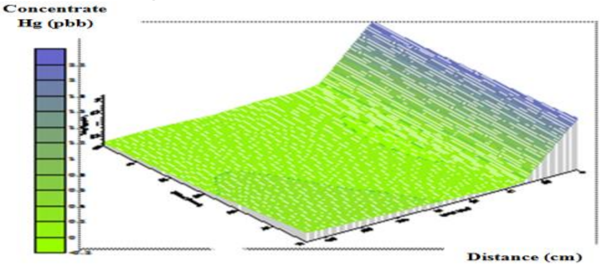

Figure 2: The Relation of Concentration Hg Toward Distance of 15 cm; 30cm;, 45cm During 2.5 Hours With Time Interval of Every 30 Minutes.

Ion Hg was experiencing a greatest decreasing concentration for all areas on the 30th minute of remediation process. The greatest decreasing is experienced by area II, that was reaching 1,992 ppb. The concentration of Ion Hg in the area I is continued to be increase with the length of the remediation process. For Area II is experienced a decreasing of the Hg concentration in the 120th minute, with the final concentration about 0.15 ppb. For the area III, after it is experienced a sharp decreasing in the 30th minute of remediation, a decreasing of the concentration is still kept remaining. Leachate remediation process for the succeed Hg content is caused by achieving a great efficiency process that was 93.2% . Hg was a volatile element in the temperature of 25° C **[15].** So that the possibility of Hg was also have a lot evaporated during the remediation process because the temperature in the reactor is increased. The most efficient remediation process in area III (which was far from the cathode) and on the shortest time (30 minute). So that it was farther the observation area form the cathode, the reduction of Hg ion concentration is increased for a longer remediation time.

3.1.2. The Content of Copper (Cu).

The research result about content of copper (Cu) in the leachate can be seen in Figure 3

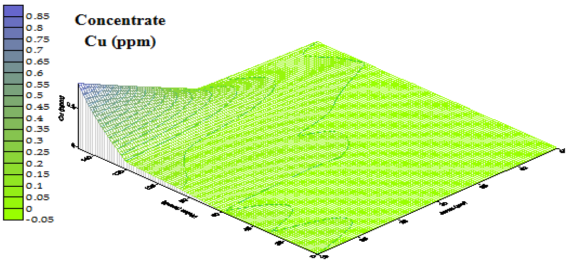

Figure 3: The Relation of Cu Concentration Against The Distance of 15cm, 30cm, 45cm for 2.5 Hours with The Time Interval in Every 30 Minutes.

Cu metal ion concentration is so increased for the 120th minute's observation time and the 150th minute in the area I, so that after the remediation process of Cu content have been done in the area I, that was an area that closed to the cathode about 0.082 ppm, while the area II about 0,072 ppm and the area III is not detected. As longer as the remediation process that was conducting, as much the accumulation of Cu^{2+} metal ion that is more to be marked by as increasing the Cu^{2+} ion concentrations in the area closed to the cathode. As closer the sampling point to the cathode rod, as greater the concentration of Cu^{2+} metal ion that was detecting and that metal ion concentration was increasing at the longer remediation time. In addition, the area around of the cathode is also occured a flow electromigration. The electromigration flow caused by the movement of ion parallelly to the surface of the particles belonging to the electrode and during the transfer, that ions was migrating into the surrounding of stream by clinging **[16].** The analysis that is conducted for a sample that was taking from the deposition on the cathode rod after the remediation process is ended was exhibitioning a Cu^{2+} metal ion concentration about 75.605 ppm, which meant that the Cu^{2+} metal ion is bounded to the cathode, during the remediation process was taking place.

The remediation process of Cu^{2+} metal ion on the leachate can not be said unsuccessful due to a certain that was a far from the cathode (area III), the ion content of Cu^{2+} metal is not detected until the end of the process. But for the close cathode distance, Cu^{2+} ion is not decreased. Overall the efficiency of process was successful for an area I about 0.8%, for the area I about 0.07% and for the area III can not be calculated because the level of Cu^{2+} is not detected.

3.1.3. The Content of Zinc (Zn).

The research results about the content of zinc (Zn) in the leachate can be seen in Figure 4.

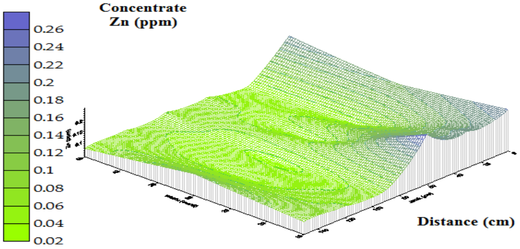

Figure 4: The Concentration Relation Between Zn Against The Distances of 15cm, 30cm, 45cm during 2.5 Hour with Time Interval in Every 30 Minute.

The Zn^{2+} concentration in the leachate on each observation areas generally, there is increased and there is also decreased. it can be seen in Figure 4. For the area I which has distance about 15 cm from the cathode, Zn^{2+} ion concentration was higher than the area II and III for whole observation time except at the 150th minute time. While the second area is experienced the concentration decreasing of Zn^{2+} ion except for the 150th minute time that infact had increased. As for area III or outside of electrode area (45 cm from the cathode) was happening a concentration decreasing of Zn^{2+} ion for all observation time than the observation time of 0 minute or before the remediation process would be conduct.

A decreasing of Zn^{2+} ionconcentrationon the 30th early minute in the remediation process due to the electromigration process, whereas Zn^{2+} ion that is positively charged would be tend to the cathode. Applications of DC electric domain can be induce a migration of ionic from the contaminant. Ion migration or electromigration was the charged chemical species movement on the pore fluid displacement. Anions (negatively charged ion) would be move towards the anode (positive electrode) and cation (positively charged ion) would be move towards the cathode (negative electrode) **[17].** The binded cathode of Zn^{2+} ion was more, it is evidenced by the amount of Zn^{2+} content in the sediment that is taken on the cathode rod about 109.704 ppm. The remediation process was also success to decrease a Zn^{2+} content from the initial concentration by an average about 0.194 ppm to be 0.096 ppm at the 150th minute time of remediation process.

The efficiency process of the remediation against the Zn^{2+} content in the leachate was greater than for ion of other metals. Overall the efficiency value for the area I, II and III respectively about 59.9%, 17.7% and 66.5%. This thing showed that for the remediation efficiency of Zn^{2+} ion in the leachate was requiring a short time and the distance is not too influential.

3.1.4. The Content of Lead (Pb).

The research result about the content of Lead (Pb) on the leachate can be seen in Figure 5.

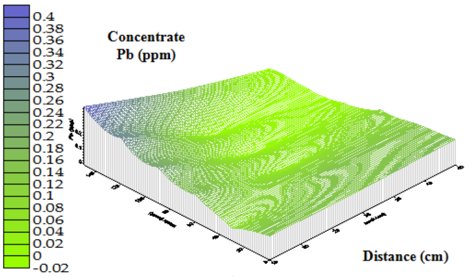

Figure 5: The Relation of Pb^{2+} Concentration Towards The Distances of 15cm, 30cm, 45cm During 2.5 Hour with The Time Interval in Every 30 Minute.

The concentration of Pb metal ion, in this case Pb^{2+} was happening a decreasing on the time of 30the minute of remediation process, and that decreasing is occurred in all observation areas. The largest decreasing is experienced by the area I about 0.080 ppm. For the 60th minute of the remediation time, the concentration of Pb^{2+} ion in the area II and III are continued to be decrease, but the opposite thing was happening on the area I where the Pb^{2+} ion infact to be increase. Distance is also decided a remediation process efficiency of Pb^{2+} ion, in addition to the length of remediation time. Where as greater the distance a sampling of the cathode, as greater the reduction of Pb^{2+} ion concentration that occurred and as longer the process to be done more, as great the decreasing in the concentration of Pb^{2+} ion is showed.

This remediation process was effective for restoring the contaminated leachate by Pb^{2+} ion . It is shown form the reduction of Pb^{2+} ion content in the leachate during the remediation process and it is binded at the cathode with the Pb^{2+} concentration in the sediment at the cathode about 75.6 ppm. This was also happening because of Pb that is contained in the water to form a $PbOH^{+}$**[15].** The reaction is:

$$Pb^{2+} + H_2O \longrightarrow PbOH^{+} + H^{+}$$

The positive charge would be quickly withdrawn by the cathode. In addition, the most of Pb ion was reacting with the complexing subtances (ligands) either organic or inorganic. Dominant inorganic ligands that existed in either the natural water source or sources of pollution namely Cl, $S0_4^{2-}$, HCO_3^-, F^-, sulfide and phosphate species **[3], [15].** If Pb^{2+} was reacting to the sulfate anions and forming a $PbSO_4$, as well as also with the chromium that was forming a $PbCrO_4$. These salts were not soluble by water or forming a precipitate. In the free metal ion aerobic state, especially exist in the low pH, and by the increasing of pH, carbonate and then oxide, solid hydroxide woul be precipitate **[14].**

The efficiency of remediation process towards the Pb^{2+} metalion content is fluctuated. For the area I, the remediation process is efficiently carried out in the 30th minute and for a longer time, the efficiency value was decreasing. For area II, the remediation process efficiently is carried out on the 90th minute of remediation process and the longer of its efficient value process, as for area III, the most efficient remediation process was at time of 90th, 120 and 150 minutes because the concentration of Pb^{2+} ion is not detected again, so that by overall the efficiency value for area III was about 100% and it is a largest value compared the other areas. This meant that for the leachate remediation from contaminating of Pb^{2+} ion is needed the longer time for the greater distance from the cathode.

3.1.5. The Content of Chromium (Cr)

The research result about the chromium (Cr) content in the leachate can be seen in Figure 6.

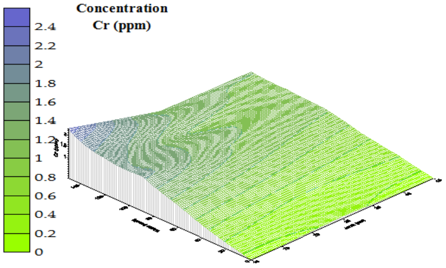

Figure 6: The Relation of Cr Concentration Against The Distances of 15cm, 30cm, 45cm During 2.5 Hour with The Time Interval in Every 30 Minutes.

The concentration of chromium (Cr) in general have a concentration increasing trend, in step with the length of remediation time. The greatest chromium concentration increaing was happening in the area I by achieved a high final Cr concentration at the time of 150th minute that was about 2,314. For the area III was also happening an increasing, in line with the length of the remediation process, but its increasing is not as great as what was happening in the area I. The final Cr concentration in this area that was 1,268 ppm or to increasing about 1.03 ppm from the initial concentration. meanwhile in the area III, the increasing of Cr concentration is also occured and the greatest increasing for this area to be observed on the remediation time of 60th minute, as amount 0.237 ppm. The final of the remediation process on the area III has a Cr content about 1,216 ppm or it is increased about 1,117 ppm from the initial concentration. The as further the sampling point of the cathode as the Cr ion concentration to be decrease. The highest Cr concentration in the areaI than other areas, it was possible the migrating Cr^{3+} ion toward the cathode is accumulated in the area around of cathode and the concentration of Cr^{3+} to be increase.

The Increasing of Cr content as longer as the remediation time is possibled because during the electrolysis remediation process happened, Cr^{3+} was in the *cationic hydroxides* format such as $Cr\,[OH]^{2+}$ and it would be move towards the cathode, while the Cr^{6+} was in the *oxyanions* format such as $CrO4^{2-}$. that is moved towards the positive charge (anode) **[18].** So that the increasing phenomenon of Cr in the area II and III are influenced by the presence of *oxyanions* such as $CrO4^{2-}$. However, the greatest content of Cr is stilll observed on the cathode, it is evidenced by the high of Cr content in the sample of sediment on the cathode rod which was about 74828.98 ppm. This is proved that the remediation process was able to bind Cr in the leachate.

The remediation process of Cr metal ion in the leachate was not very effective because that metal ion concentration is not decreased, but it is actually increased by the efficiency values about -2237.4%, 432.8% and 1128.3% for areas I, II and III. The decreasing of remediation process efficiency of Cr in the area I, because area I was close to the cathode so that Cr metal ion is accumulated there, because the binding based on the cathode charge. The decreasing of efficiency processes in the area III due to the formation of the oxyanion from Cr^{6+}into CrO_4^{2-} that was negatively charged, so that the flow direction of Cr metal ion is migrated towards the anode. For the area II was possibled due to the polarization process after the electricity flow has been removed for observation. Beside that, the increasing of Cr content due to the removing of bond with the ligands that were forming a complexes with Cr. For the area I, the remediation process of metal ion where that thing meant as greater the distance from the cathode, as it is required a longer time to remediate the Cr metal ion from the leachate.

3.1.6. The Content of Cadmium (Cd).

The analysis of cadmium (Cd^{2+}) content is still conducted, although on the initial sample is not detected, considering the garbage that there in Piyungan landfill was a household and industrial trash that was an artificial sources for the content of Cd^{2+}. The analysis result against the sample that was taking at time of 0, 30, 60, 90, 120 and 150 minutes when the leachate remediation process to be done, actually for those all samples, the content of Cd^{2+} is still not detected. However, at the time of deposition sample on the cathode was analyzing, it shown that there was a Cd^{2+} metal ion with a concentration about 1,907 ppm. This thing was giving a conclusion that cadmium is still existed in the leachate, but its level was so small so that it can not be detected by devices which was below of 0.01 ppm. Cd^{2+} metal ion may formed a complexes with macro organic molecules and it is settled on the leachate container base in the landfill, while at the time of sample taking is not reached to the container base, so that the possiblity of Cd^{2+} to be ending up was also low. Besides the presence of high rainfall which is caused a decreasing of heavy metal ions concentration in the leachate sample.

3.2. The Effect of Remediation Process Against Leachate pH.

The data of research result about leachate pH at the remediation time of 0, 30th, 60th, 120th and 150th minutescan be seen in Figure 7.

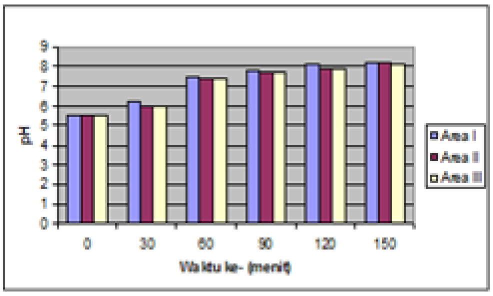

Figure 7: The Relation of pH Towards The Time On Areas I, II and III

The value of pH was happening an increase, in line with the length of remediation time. The initial pH as amount of 5.5 is continued to be increase until the final pH on the time of 150th minute as amount of 8.2 for areas I and II, while the area III as amount of 8.1. All observation areas was experiencing an pattern increasing of pH value. The pH value that was more increasing from the initial leachate pH as amount of 5.5 is indicated that the leachate was acidic. The increasing of pH was going on during the remediation process and it indicated the average value about 8.2 for all areas and indicated that the leachate became an alkaline.

Alkaline condition was indicating that the high positively ion charged content or its hydroxyl ion content that a lot. The increasing of pH indicated that there was an exemption of positively charged ion of its salt, thus it was giving a contribution against the solution positive charge. Metals in the water presenced as simply in the form of free metal ion that is surrounded by coordinated water molecules. The water electrolysis process that occurred at the cathode during the remediation process would be absolve the OH^-, that was a water cluster and surrounding the metal ion so that the metal ion would be present in the form of its ionic that was positively charged **[19].** It was also there a metal ions where its reaction was produced a positive ion as what is occurred on Zn and metal ion that was form in a complexes by a ligands and have a positive charge as what did happen on the cadmium with the following reaction **[3]:**

$$Cd^{2+} \quad + \quad CN^- \longrightarrow CdCN^+$$

The contribution of positive ions due to the high leachate pH effect. As longer the remediation process to be done, as great the possibility to be happened and the presence of calor as the catalyst can be accelerating the reactions to be occurred.

3.3. The Influence of Remediation Process Towards the Resistivity On Leachate.

The research results about the resistivity during the remediation process of leachate can be seen in Figure 8.

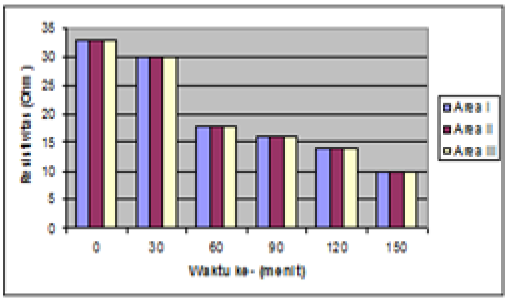

Figure 8: The Relation of Resistivity Against Time On Areas I, II and III.

Resistivity value in each observation times of area I, II and III totally, where there was a decreasing of resistivity. The measurement of resistivity was important to know how the effect of a concentration decreasing of heavy metals towards the electric current barrier. Actually as smaller the concentration of metal ions in the leachate as smaller the barrier flow to be obtain. The resistivity measurement data can be viewed on. This matter is caused by as greater the electrical conductivity as smaller the barrier. The theory was accordance to the equation that the resistivity (ρ) was inversely proportional to the conductivity. The stacking of metal ion on the cathode rod can be a conductor of electric current. As much the metal ion that accumulated due to the remediation process on the cathode rod, as with the length of time duration for the remediation would be the conductor of electric current that was flowing during the process.

3.4. Phenomenon That Occurred During The Leachate Remediation Process

At the beginning of remediation (for the first 30 minute) there a changing around of electrode that was occurring about ± 5 minute after the current flow was running. At the cathode there were a white chocolate blobs, while at the anode there were a white froth and it looked like a boiling water (Figure 9).

Figure 9: The Changing That Occurred During The Remediation Process.

When the process finished, at the cathode there were a piling up wadding of reddish brown colored and there were a silvery gray as well as the white froth of the anode was getting white dirty. After the remediation process finished, on the cathode rod there were a deposit of dark gray colored. There were like a mud but there was a strong clinging to the cathode rod, so that the cathode rod became like rusty iron.

The beginning phenomenon was form a bubbles existence like a boiling water at the cathode and anode as a sign that the water electrolysis process was going on. The scum that appeared was a gas that is released because that process **[11],** such as:

In the anode: $2H_2O \rightarrow 4H + O_2\ (g) + 4e^-$
In the cathode: $2H_2O + 2e \rightarrow 2OH^- + H_2\ (g))$

The difference of color froth at the cathode and anode due to the cathode metal ion begun to close and its color affected the color froth that is formed.

Brick red or orange color that appeared on the leachate surface was an original color of Cu and gray color that appearead is originated from Hg, Zn, Cd and other heavy metals that have the original color was gray. There was also the metal ions which was reacting catalyzed by the calor and it formed a self color like oxide zinc that was usually white would change become yellow on the heating. Its CdO variety colors from yellow-green until brown close to black, was depending on the heating history **[15], [20].** In addition the golden brown color was also the color of trivalent chromium metal 3 (Cr^{3+}) **[21]**.

4. Conclusions

1) In the leachate samples from the Piyungan landfill that taken on February 09, 2009 is contained the ionic Mercury (Hg) as amount of 2,149 ppb, Copper (Cu) of 0.074 ppm, Chromium (Cr) of 0.272 ppm, Lead (Pb) of 0.161 ppm, and Zinc (Zn) of 0.340 ppm. While the Cadmium (Cd) is not detected in the leachate but after it was flow-ing by the electric current, it is contained at the sediment in the cathode about 1,907 ppm. The concentration of metal ion is not same for each times because the waste that is contained in the landfill was also different.
2) The effective remediation process to decrease a metals concentration in the leachate in the short term but the efficiency was different for each metal types, it depended on the nature of the metal itself.
3) The process efficiency is very influenced by the distance from the cathode and the length of the remediation process. As closer to the cathode, as the time required for the remediation process is getting shorter, so that as farther the distance from the cathode, as the process of remediation would be efficient for a longer remediation time.

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